Large Scale Structure in X-ray Surveys

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THE ASTROPHYSICAL JOURNAL, 353: L3–L6, 1990 April 10

THE X-RAY FLUX DIPOLE OF ACTIVE GALACTIC NUCLEI AND THE PECULIAR MOTION OF THE LOCAL GROUP

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Received 1989 December 4; accepted 1990 January 19

ABSTRACT

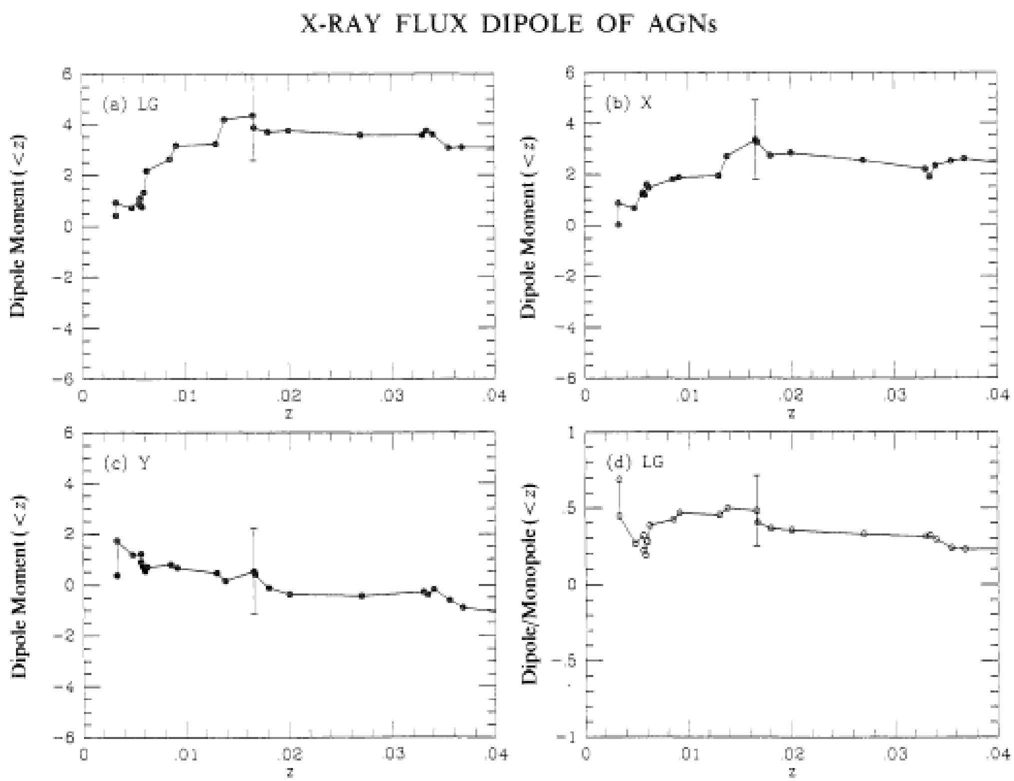
An X-ray flux-limited sample of 30 AGNs detected with the *HEAO 1* A-2 experiment, which is complete for $|b| > 20°$, is used as a tracer of the total gravitational mass distribution in the nearby universe. The dipole moment of the flux saturates at about $z = 0.017$ and gives the direction $(l, b) = (313°, 38°)$ with an error circle of about 30° in radius. This direction is 39° away from the direction of the Local Group's motion with respect to the microwave background radiation. The amplitude of the dipole is about 50% of the corresponding monopole. Applying our data to linear perturbation theory, we get a value of $b\Omega_0^{-0.6}$ close to previous results using optical galaxies and somewhat greater than values obtained from *IRAS* galaxies. This suggests that the X-ray emission from AGNs traces the underlying mass distribution at least as strongly as optical and IR emission from galaxies.

Subject headings: cosmology — galaxies: nuclei — X-rays: sources

Resulted from a summer project 1989

Background

- The Local Group (LG) moves towards (l,b)=(268°,27°) with respect to the Cosmic Microwave Background (CMB)
- Dipole moment of the mass distribution around the LG is responsible for the motion. Look for this mass unisotropy using “tracers”.
- All-sky surveys needed to investigate the dipole moment of this mass distribution.
- Analysis in this line had been made with IRAS galaxies (e.g. Yahil et al. 1986) and optical galaxies (e.g.Yahil et al. 1986; Lahav et al. 1987; Lynden-Bell et al.).
- How about the X-ray Background (HEAO-1 A2) (Boldt 1987;R. Shafer “**Don't Panic**” PhD thesis '83)?
  - Consistent-with the Compton-Getting Effect (Anisotropy caused by our motion towards an isotropic background, including special relativistic effect and shift of energy).
- How about X-ray resolved AGNs in HEAO-1 (Piccinotti et al. 1982)?



pole growth curves (eq. [1]) for the components in three orthogonal directions are shown in (a)–(c). Fig. 2d shows growth curve of the ra
ıle (eq. [2]) for LG direction. Error bars show statistical sampling errors.

The distribution of Piccinotti AGNs has a **Strong Dipole Moment** towards LG's motion w.r.t. CMB in v<4500 km/s.

If all the mass dipole comes from v<4500 km/s:

AGN bias parameter:

$$b_{AGN} = (\delta\rho/\langle\rho\rangle)_{AGN}/(\delta\rho/\langle\rho\rangle)_{mass}$$

$$\boxed{b_{AGN}\Omega^{-0.6}=2.5\text{-}6}$$

Further careful analysis of the HEAO-1 A2 Cosmic X-ray Background by Scharf et al. (2000) detected a dipole moment, even after removing the Compton-Getting effect:

$\boldsymbol{b_{AGN}\Omega^{-0.6}=1.7\text{-}7.1}$

Correlation of Cosmic X-ray Background with Galaxies

A significant contribution to the cosmic X-ray background from sources associated with nearby galaxies

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The origin of the cosmic X-ray background remains a mystery after thirty years of study. The three properties of the background radiation commonly used for tackling this problem—its spectrum, isotropy and resolved component—are well defined by observations, but do not lead to a simple interpretation. A different approach to the problem[1,2], in which fluctuations in the unresolved component are cross-correlated with galaxy catalogues, has led to the suggestion[2] that as much as 60% of the background emission can be explained by a population of X-ray sources similar to present-day optically bright galaxies. Here we point out that such analyses must allow for contributions from X-ray sources which cluster with the galaxies, but do not necessarily have a counterpart in galaxy catalogues. For realistic assumptions about clustering, we obtain a revised limit on the local X-ray emissivity due to sources correlated with nearby galaxies. Extrapolating these results up to a redshift of ~5, we find that a smaller, but still significant, fraction of the X-ray background (30 ± 15%) can be accounted for by these sources. To explain the residual background [illegible]

Nature 1993

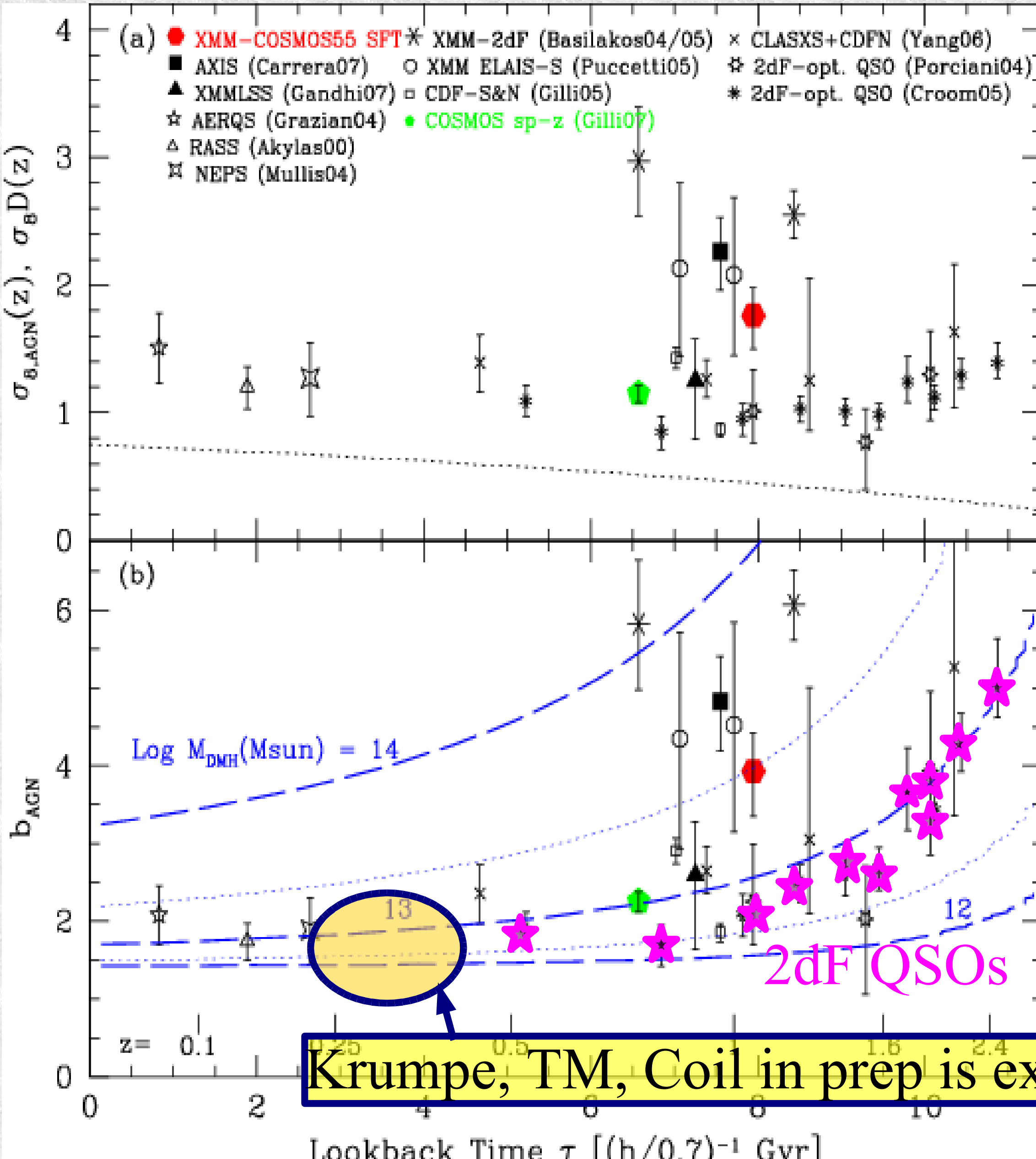
Contribution of nearby galaxies to the Cosmic X-ray Background and the local X-ray volume emissivity.

- Jahoda, Mushotzky, Boldt & Lahav 1991
- Lahav et al. 1993
- TM, Lahav, Jahoda, Boldt (1994)

2-10 keV Local Volume Emissivity
$=(4.3\pm1.2)\times10^{38}\, h_{50}$ erg s^{-1} Mpc^{-3}

- If there were no evolution, this corresponds to ~20% of the Cosmic X-ray Background.
- Provided one of important constraints in the population synthesis modeling of the Cosmic X-ray Background.

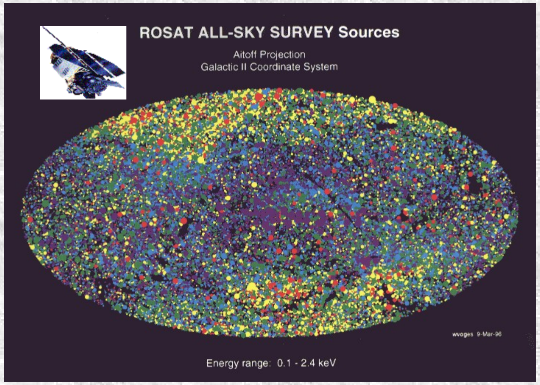
Recent Progress: Bias and Dark Matter Halo Mass

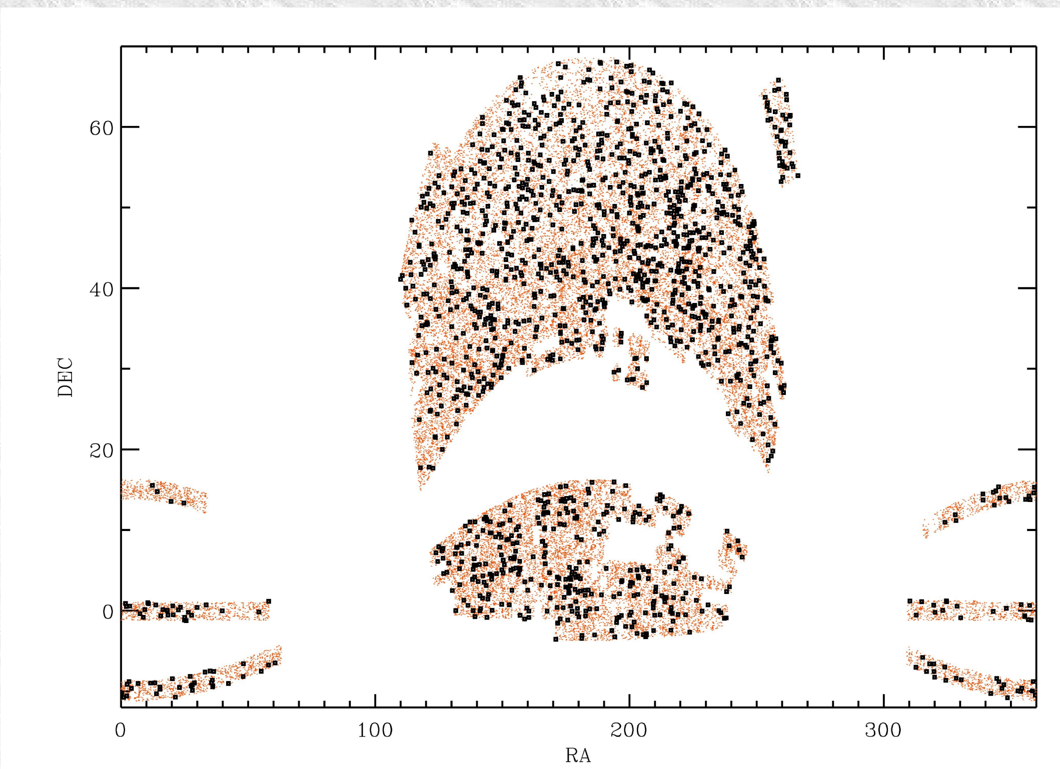


Krumpe, TM, Coil in prep is exploring this regime

- **Comparison of bias parameters from various AGN Correlation Functions.**
- Bias vs Dark Matter Halo mass from Sheth+ 2001.
- **In deep surveys, typical DMH mass hosting AGNs (Lx<10^{44} erg s^{-1}) larger than that of QSOs, at z~1.** (Gilli, Zamorani, TM+'08 with COSMOS; Coil+'09 with AEGIS survey)
- How about lower redshifts?

Samples used for the cross-correlation

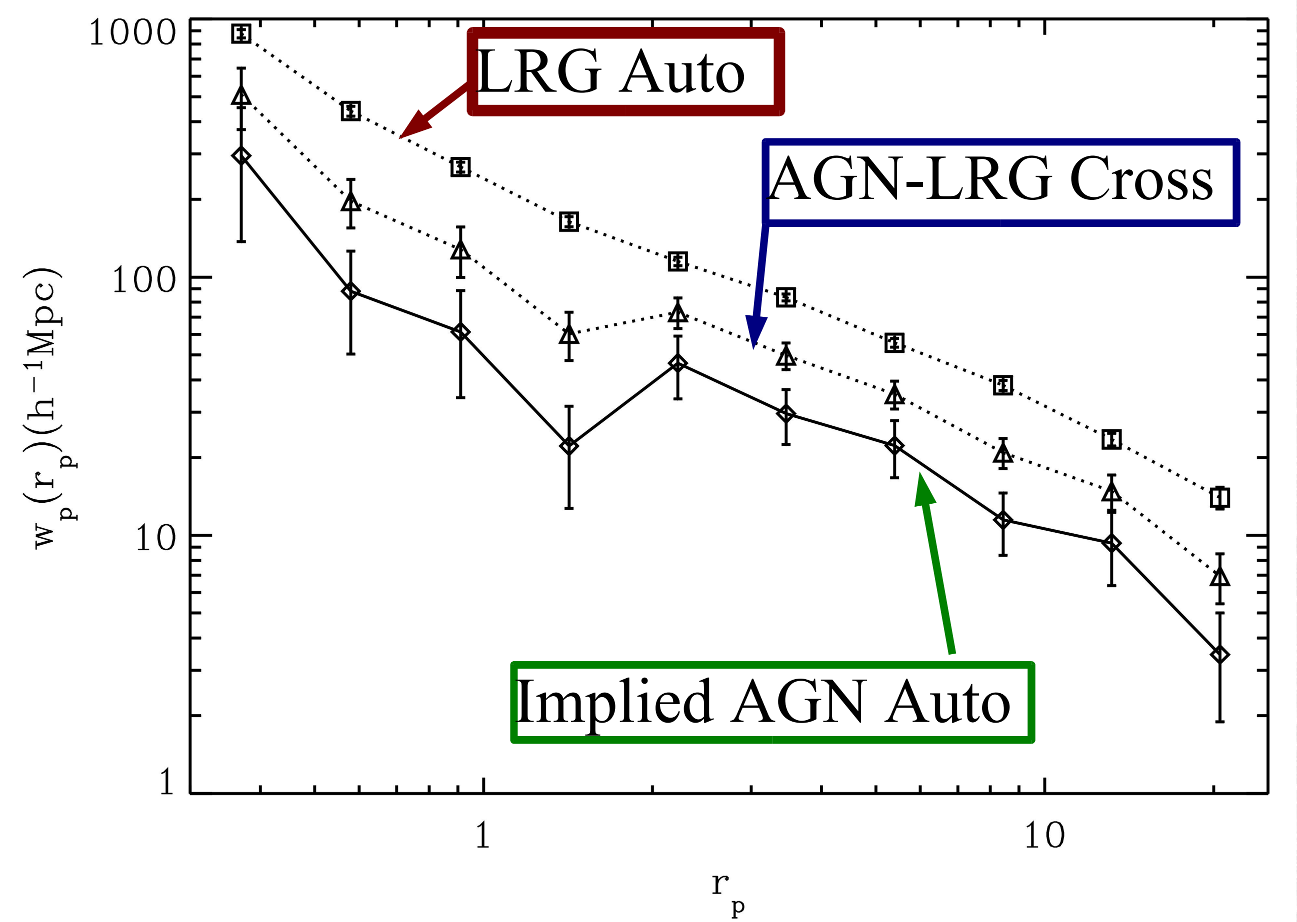




- Galaxy Sample
  - Sloan Digital Sky Survey (SDSS) Luminous Red Galaxies (LRGs)
  - MB<-21.2, 0.16<z<0.36
  - 45899 LRGs Galaxies
- X-ray AGNs:
  - ROSAT All-Sky Survey (RASS) sources matched with the SDSS Broad-line AGNs (Anderson et al. 2007), based on SDSS DR4+.
    - 1552 AGNs in 0.16<z<0.36
  - We still can't afford a volume limited sample.

Implied AGN Auto-Correlation Function

$$W_{p,\text{AGN-auto}} \approx W_{p,\text{AGN-LRG}}^2 / W_{p,\text{LRG-auto}}$$

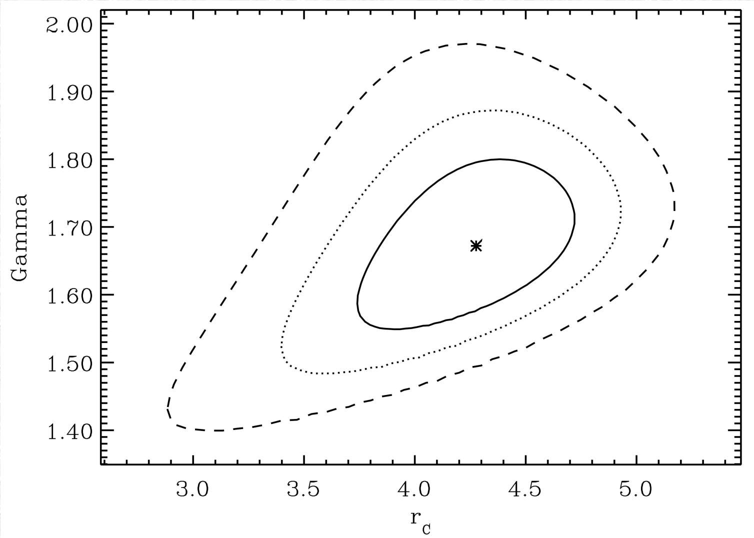


Power-law fit:

$\xi_{AGN}(r)=(r/r_c)^{-\gamma}$

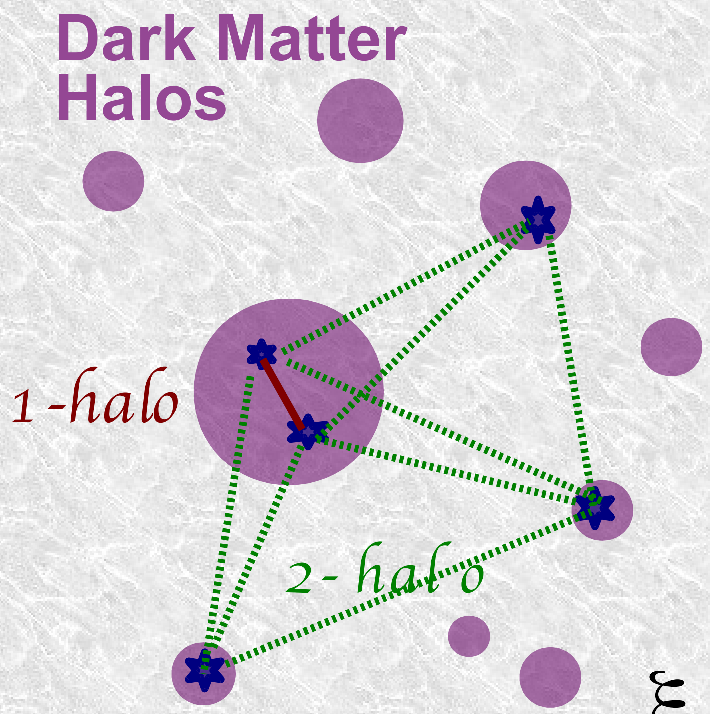
$w_{p,AGN}(r_p)=H_\gamma\, r_p(r_p/r_c)^{-\gamma}$

r_c:correlation length



Halo Occupation Distribution (HOD) Modeling of the CCF

- **Observers** see the universe as galaxies, AGNs, clusters etc..
- **Theorists** see the universe as a bunch of Dark Matter Halos (DMHs)
- How can we relate these halos with observed objects?



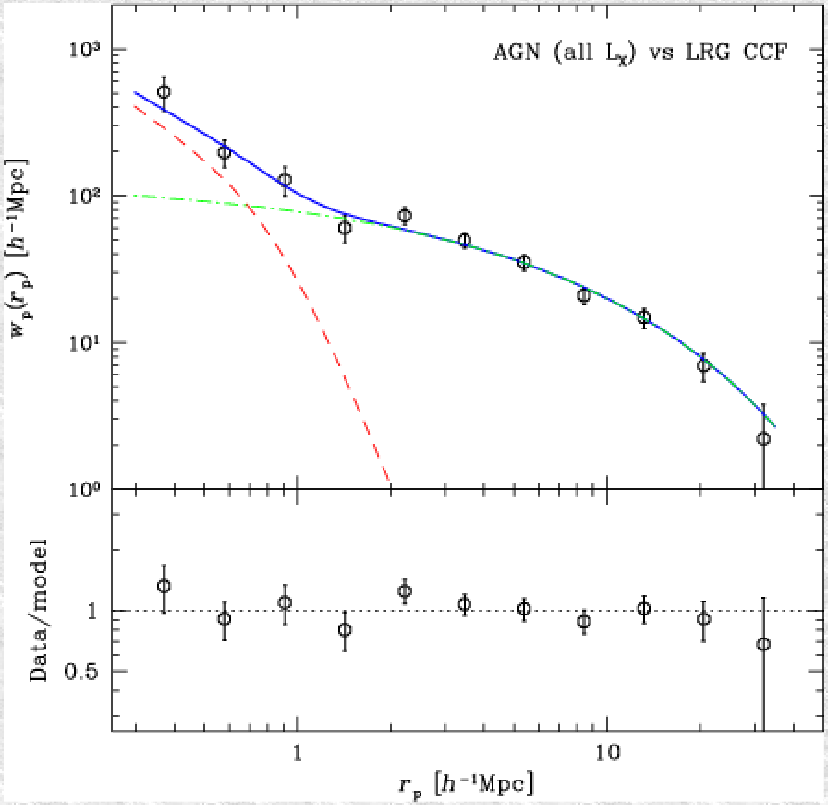
Modeling with HOD---

$\mathbf{N_{obj}(M_{DMH})}$: Average Number of the sample object in a DMH as a function of mass.

Modeling the correlation function as the sum of the contributions from pairs within the same DMH and from those in different DMHs.

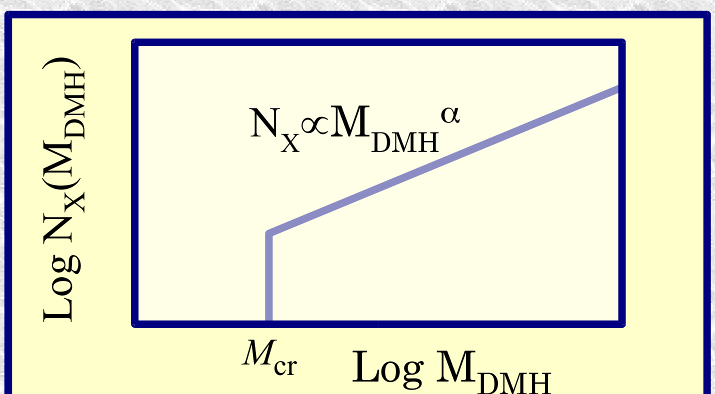
$$\xi_{\mathrm{AGN\text{-}LRG}} = \underbrace{\xi_{\mathrm{AGN\text{-}LRG,1h}}}_{\text{1-halo term}} + \underbrace{\xi_{\mathrm{AGN\text{-}LRG,2h}}}_{\text{2-halo term}}$$

Constraints on HODs for AGNs

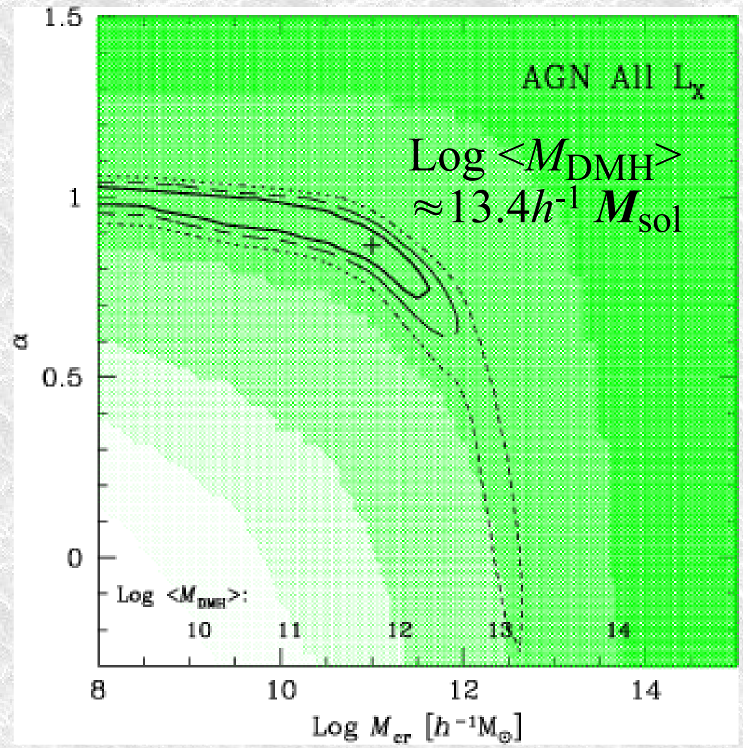


Model CCF from the combination:

- $N_{\mathbf{LRG}}(M_{\mathbf{DMH}})$ (fixed, prev. slide)
- $N_{\mathbf{X}}(M_{\mathbf{DMH}})$ (parametrized model)

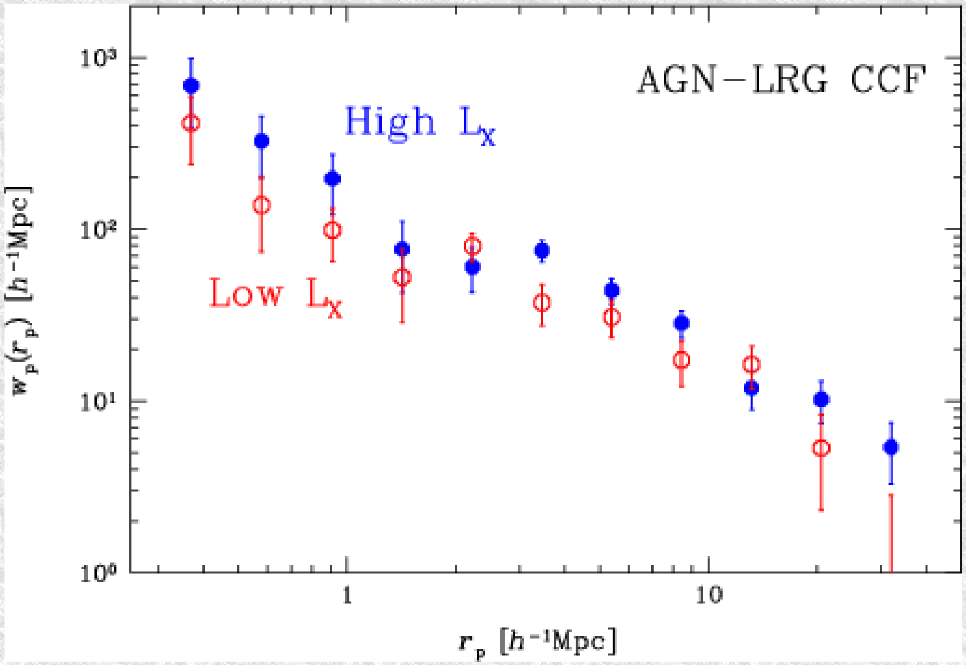


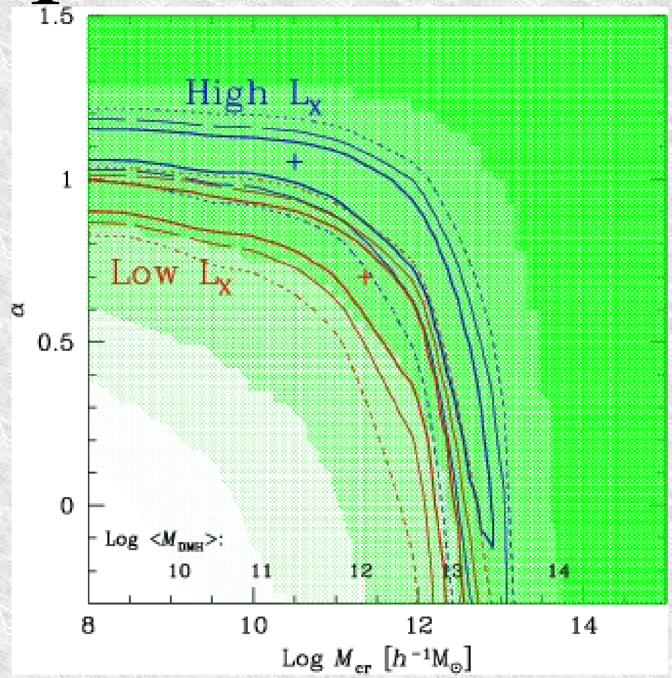
Truncated power-law HOD model for AGNs.



Confidence contours (red, $\Delta\chi^2$=1;2.3;4.6) & the mean DMH mass (green shades)

Luminosity Dependence





AGN samp.	r_c [h^{-1}Mpc]	γ	Log $\langle M_{DMH} \rangle$ [$h^{-1}M_{sol}$]
All	4.3 (+0.4;-0.5)	1.67 (+0.13;-0.12)	13.4 (+0.1;-0.1)
Low Lx	3.3 (+0.6;-0.8)	1.73 (+0.40;-0.37)	13.5 (+0.2;-0.3)
High Lx	5.4 (+0.7;-1.0)	1.86 (+0.20;-0.21)	13.2 (+0.2;-0.4)
Remark	From CCF-inferred AGN ACF		From HOD Analysis (prelim.)

Clustering is stronger for the high L_X sample.

Summary

- Elihu's quest for the large scale structure in the Cosmic X-ray Background and X-ray selected AGNs in the HEAO-1 A2 data raised a lot of questions in the evolution of AGNs:
  - The dipole moments of X-ray selected AGNs and the Cosmic X-ray backgroud lead to the question "How does X-ray emission from AGNs trace the underlying mass distribution", in terms of the bias parameter.
  - The correlation of the X-ray background with galaxies gave a constraint on the local X-ray volume emissivity, which a model of the origin of the Cosmic X-ray Background should take into account.
- Efforts to answer these questions are continuing, including detailed correlation function studies of AGN clustering and their interpretation in terms of Dark Matter Halo Occupation.